

Exploring the Many Perspectives of Distributed Air Traffic Management: The Multi Aircraft Control System MACS

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 - Stephan Romahn
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 - Ev Palmer, Nancy Smith, Todd Callantine
- Additional MACS developers
 - Michael Downs, Khan Trinh, Rick Jacoby

- Background
- One Common Situation - Many Perspectives
- MACS Views
- Operator Support and Autonomous Agent Functions
- Situation Awareness Probes
- Simulation Architecture
- MACS Usage in Recent Experiment
- Future Work

- Air traffic management research of future concepts needs to address all players including flight crews, air traffic controllers/managers and airline dispatchers adequately
- Among the ways of addressing the problem are
 - Include many participants (pilots, controllers, dispatchers) in a given air traffic simulation to work all sides of the problem adequately.
 - Include automated agents for side aspects and human participants only for the focus area of the research.

Distributed Concept (DAG)



Automation:

- CDTI
- Conflict probe
- FMS
- Data link

Flight Crew Role:

- Assure separation en route
- Plan conflict free flight paths
- Follow FMS flight paths precisely
- Self-merging and spacing

Flight
Deck



Automation tools

- Planning
- Scheduling
- Data link



Airline Operational Control

AOC Role:

- Determine preferences
- Coordinate

Planner Role:

- Generate Schedule
- Assist flight crews and ATC



Air Traffic Control

Automation

- Traffic Management
- Conflict probe
- Descent Advisor
- Data link

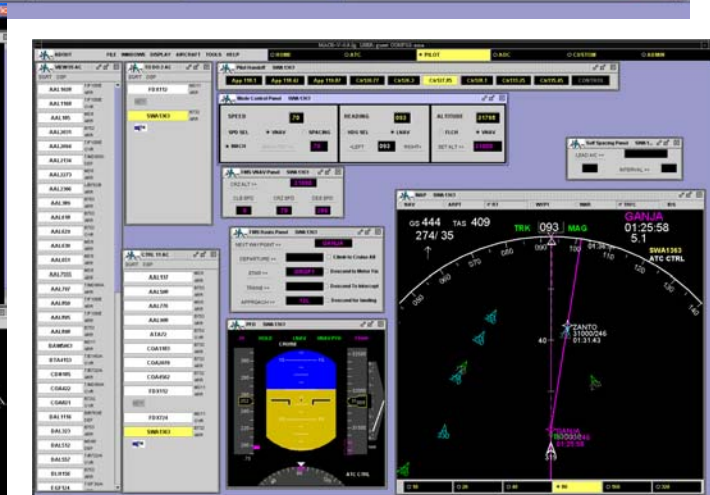
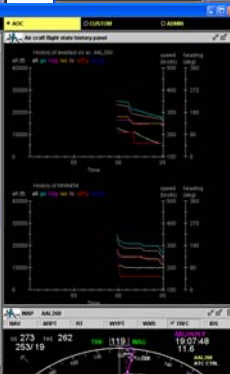
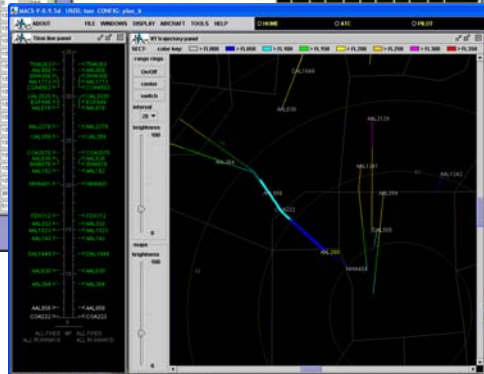
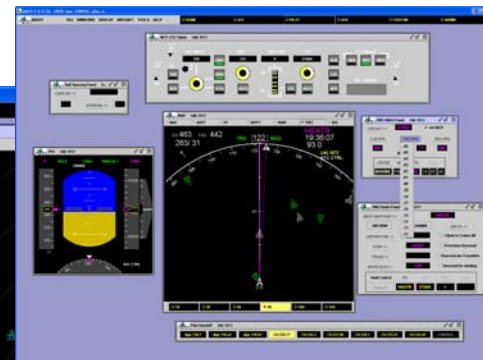
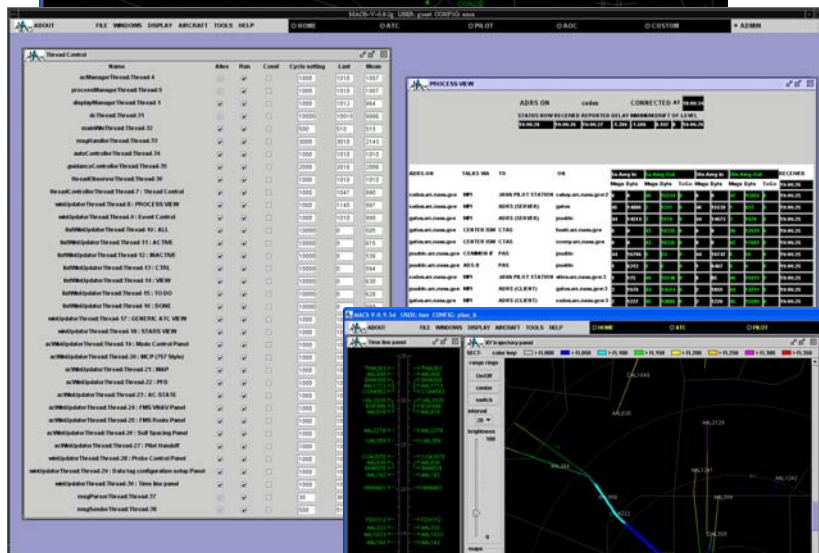
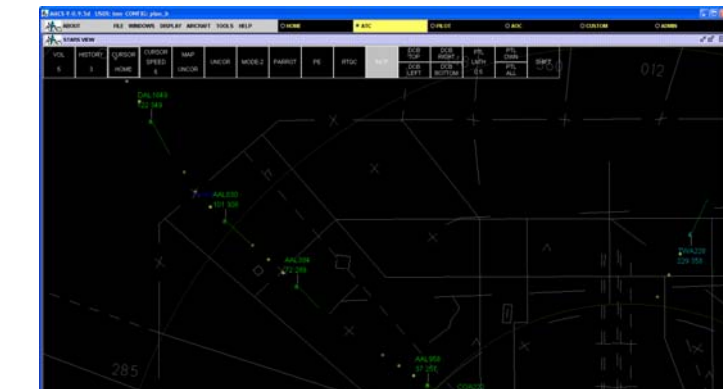
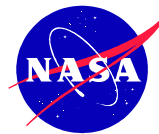
Controller Role:

- Assure separation in Terminal area
- Adjust flight paths

One Common Situation - Many Perspectives



All Perspectives As MACS Views



- All views can be configured individually by the operator
- Windows can be mixed and matched

- Only JAVA code is used
- Tested and used on Windows, UNIX and LINUX platforms with free compilers and virtual machines
- Very robust multi threaded process:
 - each window is updated by it's own thread
 - Most threads can be stopped and restarted and are automatically restarted if a problem is detected
 - All thread update rates can be configured in real-time by the operator and tailored to the particular station use
- Design goals:
 - Simple and intuitive operator interactions
 - Configurable for different levels of automation

MACS capabilities

- Full performance multi aircraft pilot stations:
 - Experienced operators typically handle 8-20 aircraft per station opposite FPL controllers
- Enroute and TRACON “FMS-like” guidance flies aircraft accurately close to the ground
- Event controller “Auto-Mode” enables automatic flight for all aircraft in a simulation
- On-line analysis of aircraft trajectories and crossing restrictions
- Several ATC views (DSR, STARS, Generic) are available and currently completed

Pilot View

MACS-V-0.9.2g USER: guest CONFIG: ama

ABOUT FILE WINDOWS DISPLAY AIRCRAFT TOOLS HELP

HOME ATC PILOT AOC CUSTOM ADMIN

VIEW 55 AC

TO DO 2 AC

Pilot Handoff SWA 1363

App 118.1 App 118.42 App 119.87 Ctr120.77 Ctr126.3 Ctr127.85 Ctr128.1 Ctr133.25 Ctr135.45 CONTROL

Mode Control Panel SWA 1363

SPEED .70 HEADING 093 ALTITUDE 31785

SPD SEL VNAV SPACING HDG SEL LNAV FLCH VNAV

MACH MACH TOT >> .70 <LEFT 093 RIGHT> SET ALT >> 31000

Self Spacing Panel SWA 1... LEAD A/C >> INTERVAL >>

FMS VNAV Panel SWA 1363

CRZ ALT >> 31000

CLB SPD CRZ SPD DES SPD 0 .70 280

FMS Route Panel SWA 1363

NEXT WAYPOINT >> GANJA

DEPARTURE >> GRGF1

STAR >> 13L

TRANS >> 13L

APPROACH >> 13L

PFD SWA 1363

HOLD CRUISE LNAV VNAVPTH 31000

300 280 260 252 240 220 200 .70

32500 32000 31500 1986

ATC CTRL

MAP SWA 1363

NAV ARPT RT WPT WXR TRFC IDS

GS 444 TAS 409 TRK 093 MAG 01:25:58 5.1

274/ 35

050 060 070 080 090 100 110 120 130 140

ZANTO 31000/246 01:31:43

GANJA 31000/246 01:25:58

10 20 40 80 160 320

MACS Single Pilot Station

MACS V-0.9.5d USER: tom CONFIG: plan_b

ABOUT FILE WINDOWS DISPLAY AIRCRAFT TOOLS HELP HOME ATC PILOT AOC CUSTOM ADMIN

MCP (757 Style) UAL1972

A/T ON
F/D ON
OFF
THR
SPD
IAS/MACH 250
LNAV
VNAV
FLCH
HDG 125
HOLD
VERT SPD 0
DN
UP
V/S
HOLD
ALT 37000
LOC
APP
A/P ENGAGE
VOR
CMDL
CMDR
DIS/ENGAGE
OFF

Self Spacing Panel UAL1972

LEAD A/C >>
INTERVAL >>

PFU UAL1972

.77 HOLD LNAV VNAV ALT 37000
CRUISE
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
ATC CTRL

MAP UAL1972

NAV ARPT RT WYPT WXR TRFC IDS
GS 463 TAS 442
263/31
TRK 122 MAG
HEATR 19:36:07
93.0
UAL1972
ATC CTRL

FMS VNAV Panel UAL1972

CRZ ALT >> 37000 set MCP
CLB SPD CRZ SPD DES SPD
250 .86 .77 280
CROSS AL PD Time
BAMBE 110 .82 50 19 55 40

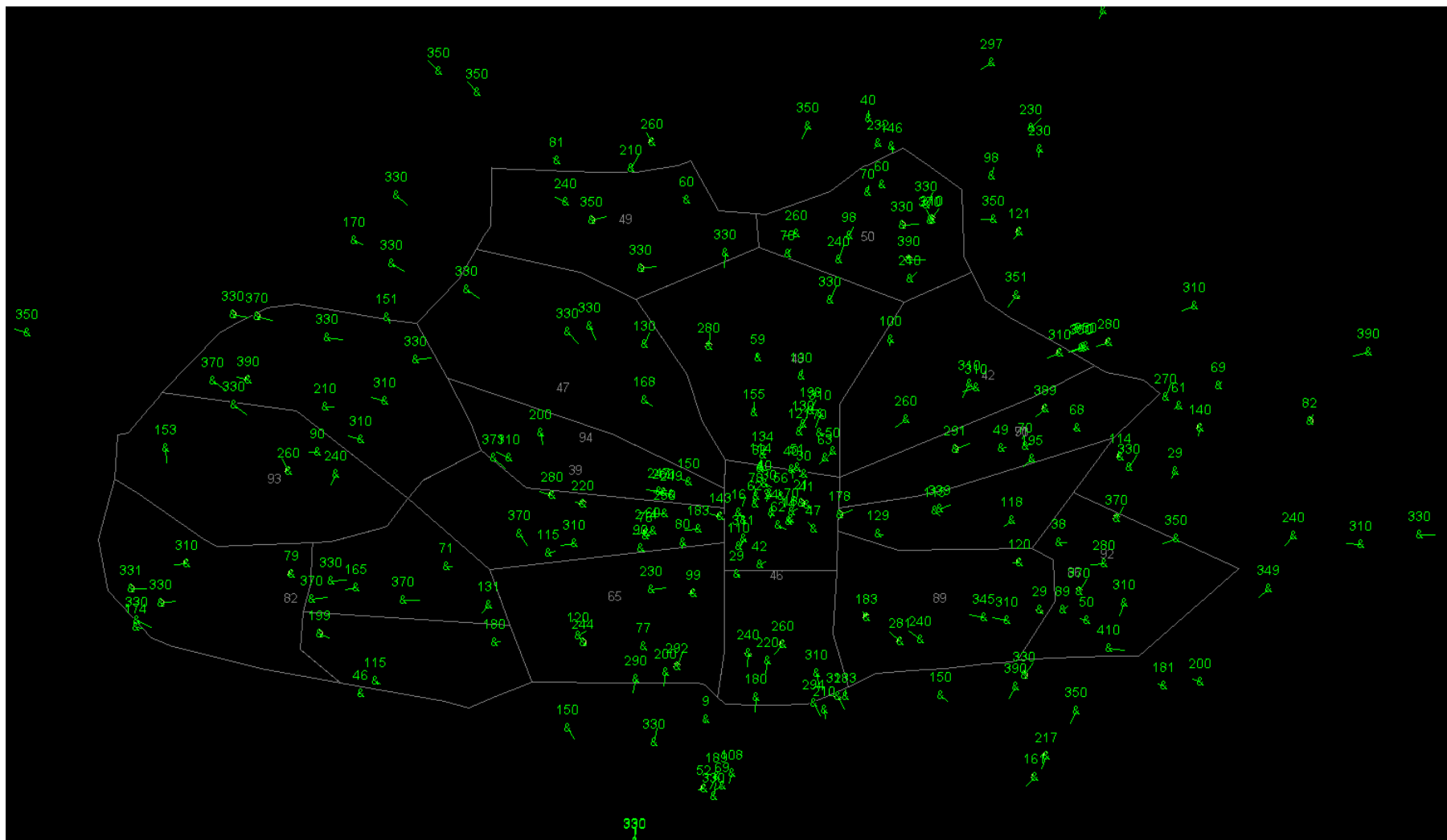
FMS Route Panel UAL1972

972
HEATR
BAMBE DIR TO >>
Climb to Cruise Alt
Precision Descend
Descend via Transition
Descend for landing
Hold Control FDK ALT SPD Turn
Engage HEATR 37000 1

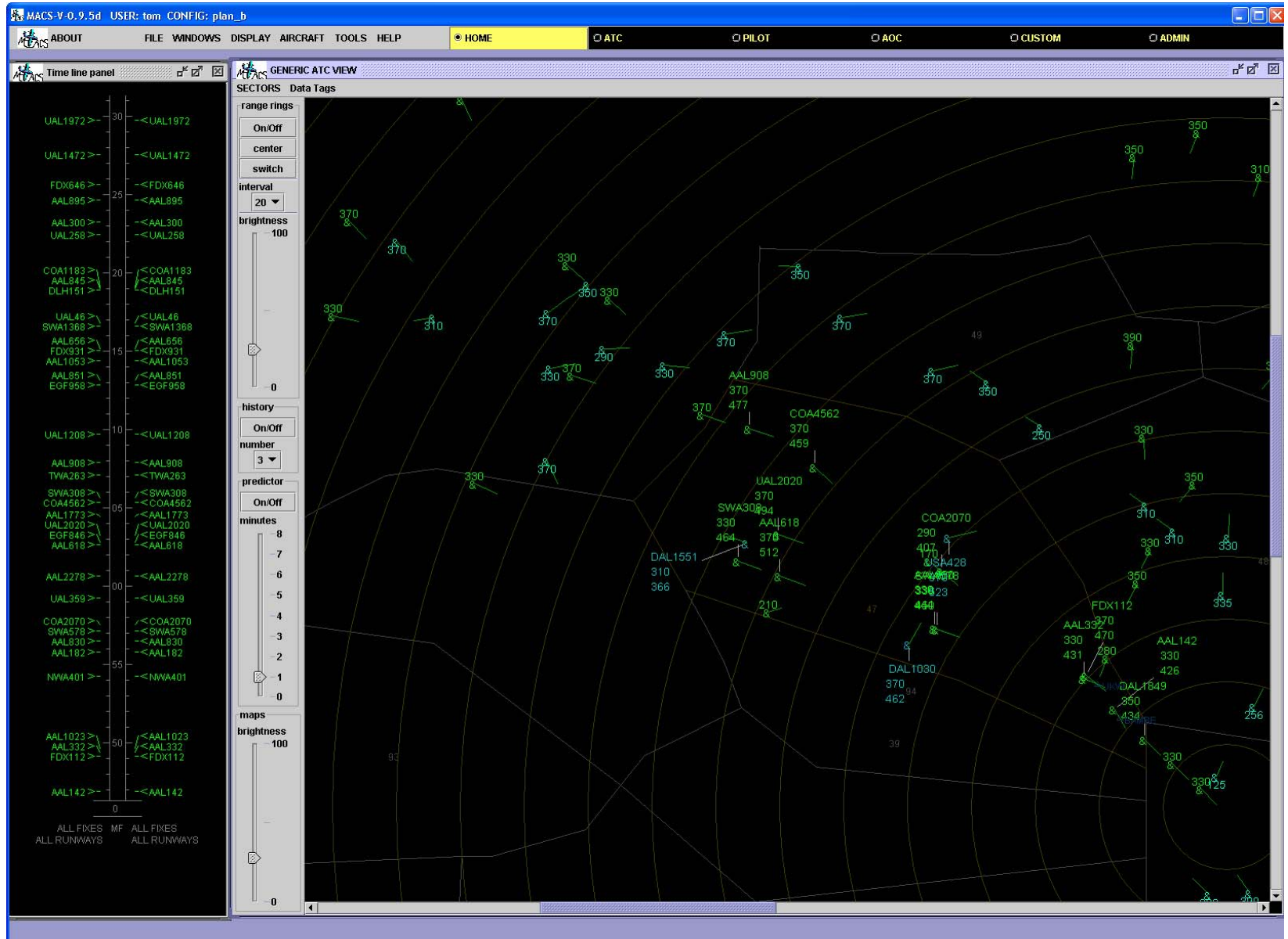
Pilot Handoff UAL1972

App 118.1 App 118.42 App 119.87 Ctr 120.77 Ctr 126.3 Ctr 127.85 Ctr 128.1 Ctr 133.25 Ctr 135.45 CONTROL

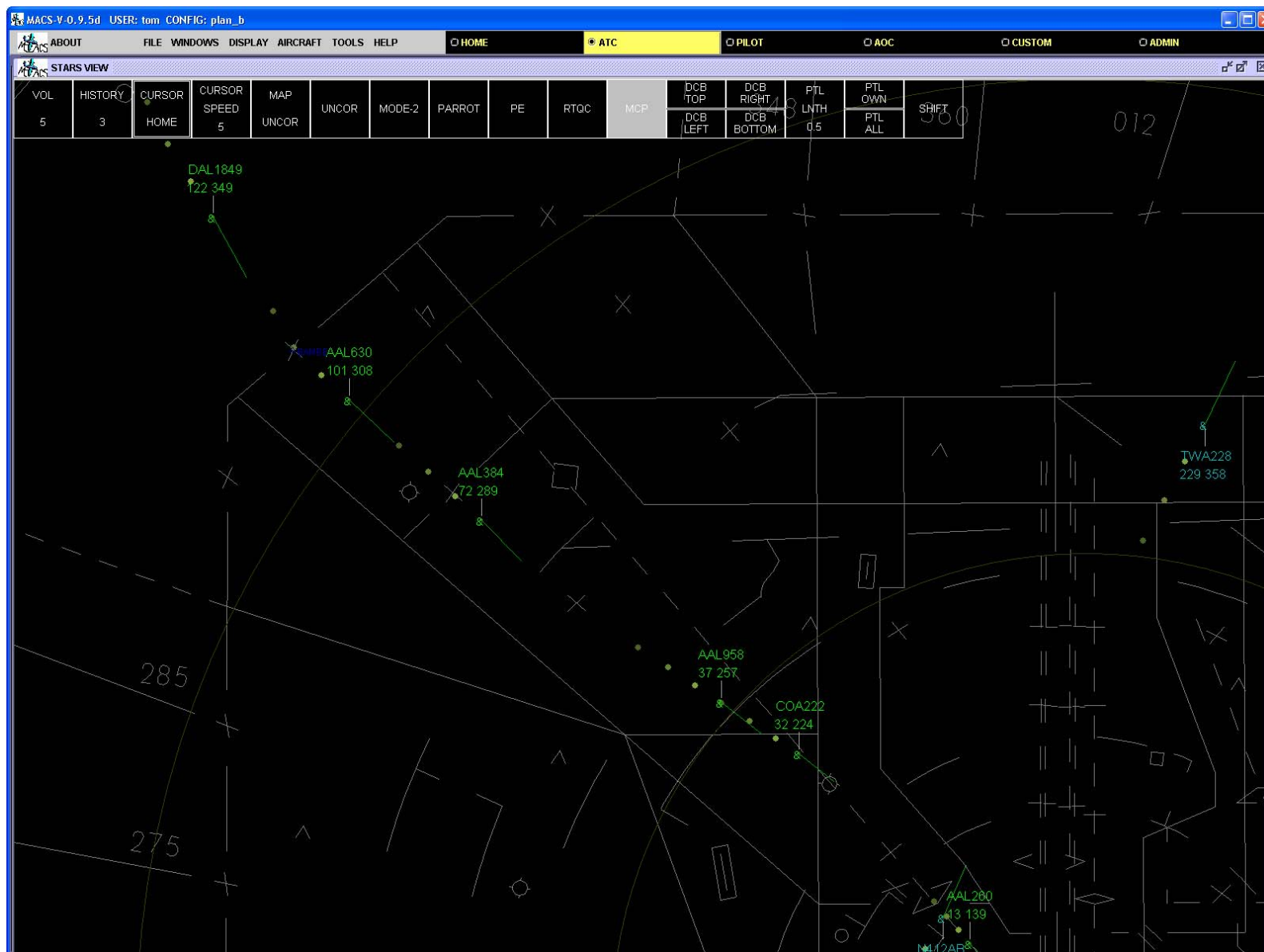
ATC view



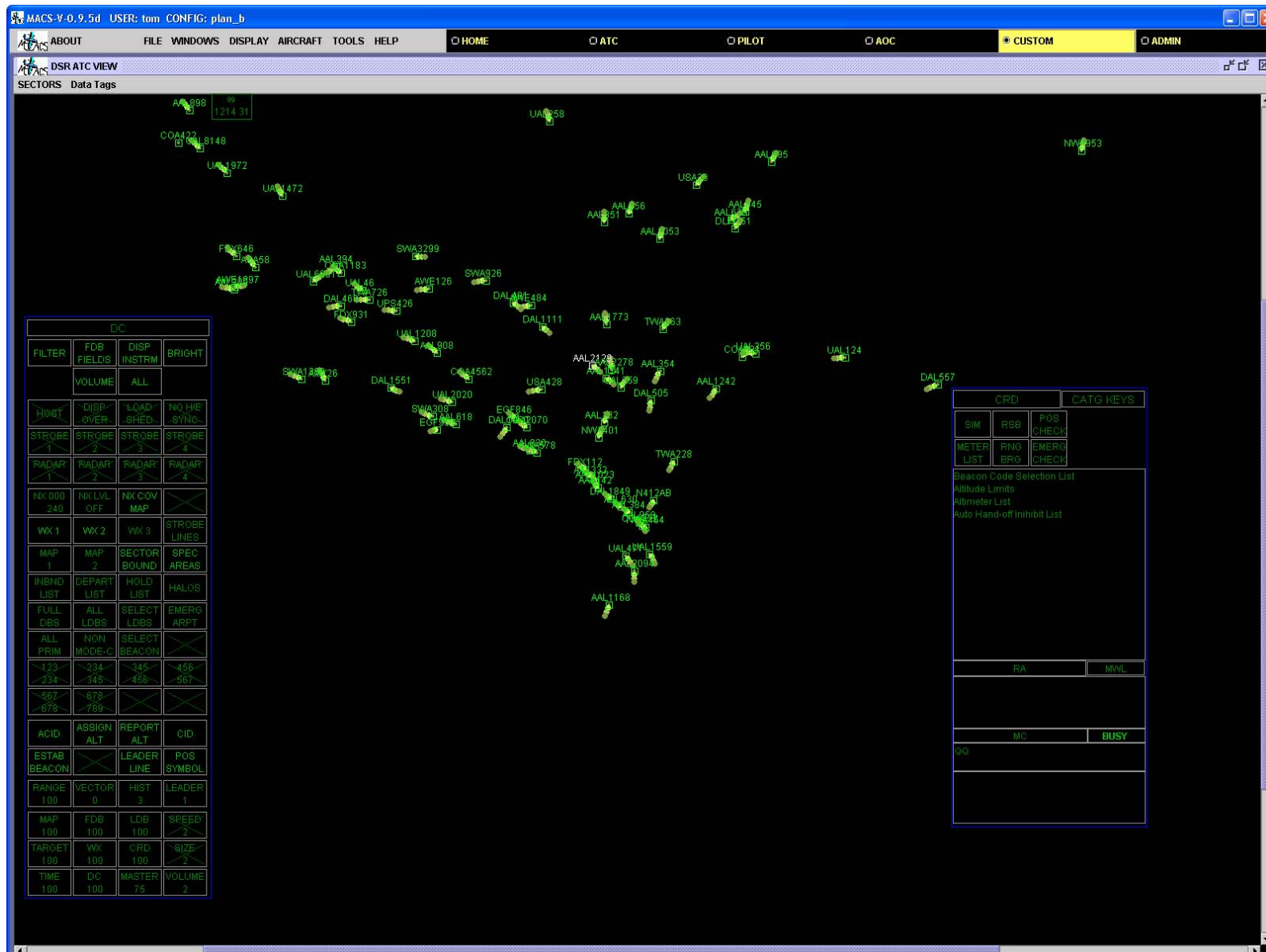
Generic ATC view



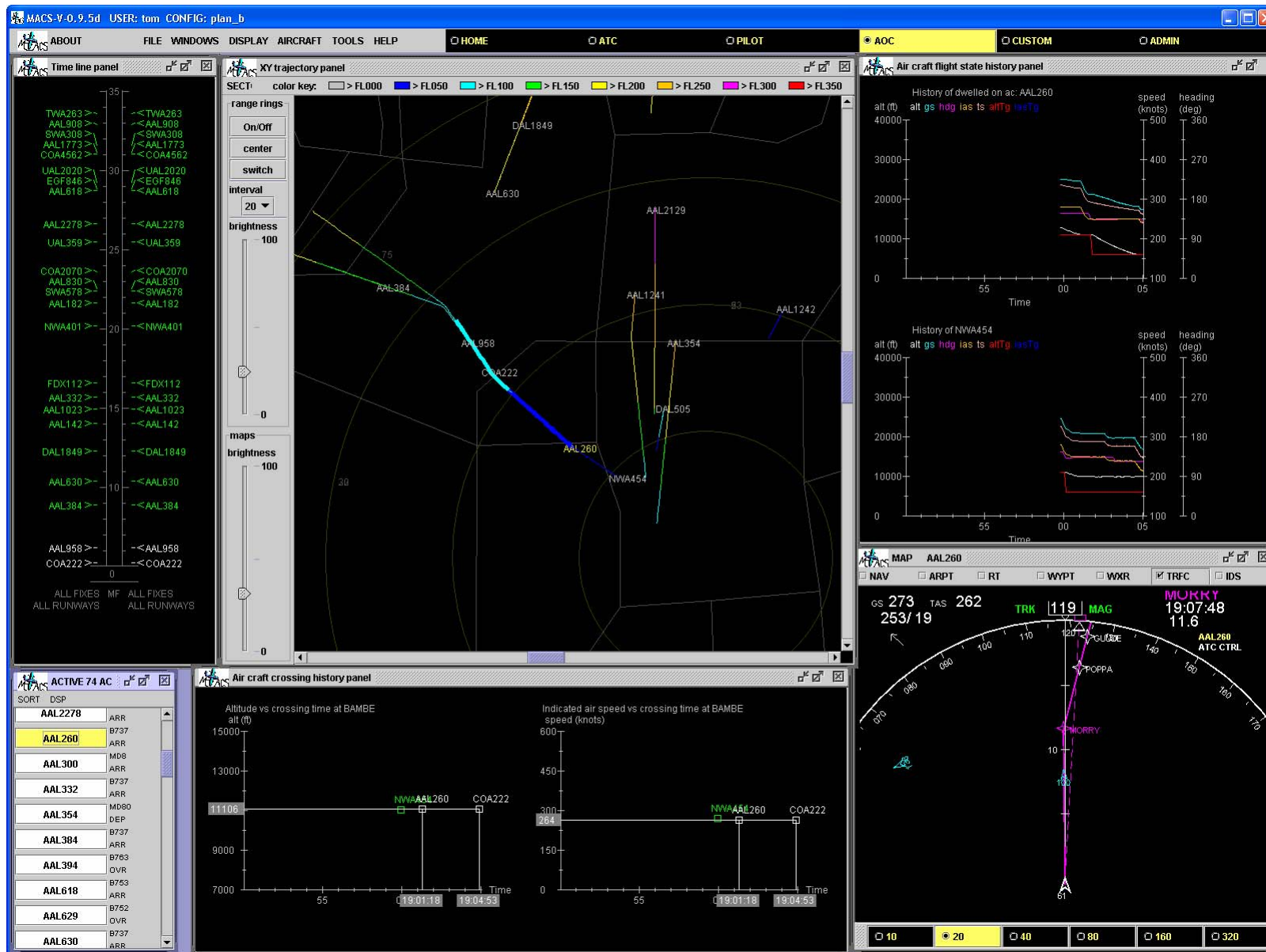
STARS View



DSR ATC View



Analysis View



Experimenter View

MACS-V-0.9.2g USER: guest CONFIG: ama

ABOUT FILE WINDOWS DISPLAY AIRCRAFT TOOLS HELP
HOME ATC PILOT AOC CUSTOM ADMIN

Thread Control

Name	Alive	Run	Const	Cycle setting	Last	Mean
acManagerThread:Thread-4	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	1007
processManagerThread:Thread-5	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	1007
displayManagerThread:Thread-1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1012	964
dcThread:Thread-31	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	10010	9986
mainWinThread:Thread-32	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	500	510	515
msgHandlerThread:Thread-33	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	3000	3010	2143
autoControllerThread:Thread-34	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	1010
guidanceControllerThread:Thread-35	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	2000	2010	2008
threadObserverThread:Thread-36	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	1010
threadControllerThread:Thread-7: Thread Control	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1047	990
winUpdaterThread:Thread-8: PROCESS VIEW	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1145	997
winUpdaterThread:Thread-9: Event Control	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	990
listWinUpdaterThread:Thread-10: ALL	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	0	505
listWinUpdaterThread:Thread-11: ACTIVE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	0	615
listWinUpdaterThread:Thread-12: INACTIVE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	0	538
listWinUpdaterThread:Thread-13: CTRL	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	0	594
listWinUpdaterThread:Thread-14: VIEW	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	0	630
listWinUpdaterThread:Thread-15: TO DO	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	0	628
listWinUpdaterThread:Thread-16: DONE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	10000	0	569
winUpdaterThread:Thread-17: GENERIC ATC VIEW	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	827
winUpdaterThread:Thread-18: STARS VIEW	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	969
acWinUpdaterThread:Thread-19: Mode Control Panel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	974
acWinUpdaterThread:Thread-20: MCP (757 Style)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	965
acWinUpdaterThread:Thread-21: MAP	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	965
acWinUpdaterThread:Thread-22: PFD	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	963
acWinUpdaterThread:Thread-23: AC-STATE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	966
acWinUpdaterThread:Thread-24: FMS VNAV Panel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	976
acWinUpdaterThread:Thread-25: FMS Route Panel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	965
acWinUpdaterThread:Thread-26: Self Spacing Panel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1000	963
acWinUpdaterThread:Thread-27: Pilot Handoff	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	978
winUpdaterThread:Thread-28: Probe Control Panel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	996
winUpdaterThread:Thread-29: Data tag configuration setup Panel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1000	993
winUpdaterThread:Thread-30: Time line panel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	1000	1010	996
msgParserThread:Thread-37	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	30	36	11
msgSenderThread:Thread-38	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	500	510	423

PROCESS VIEW

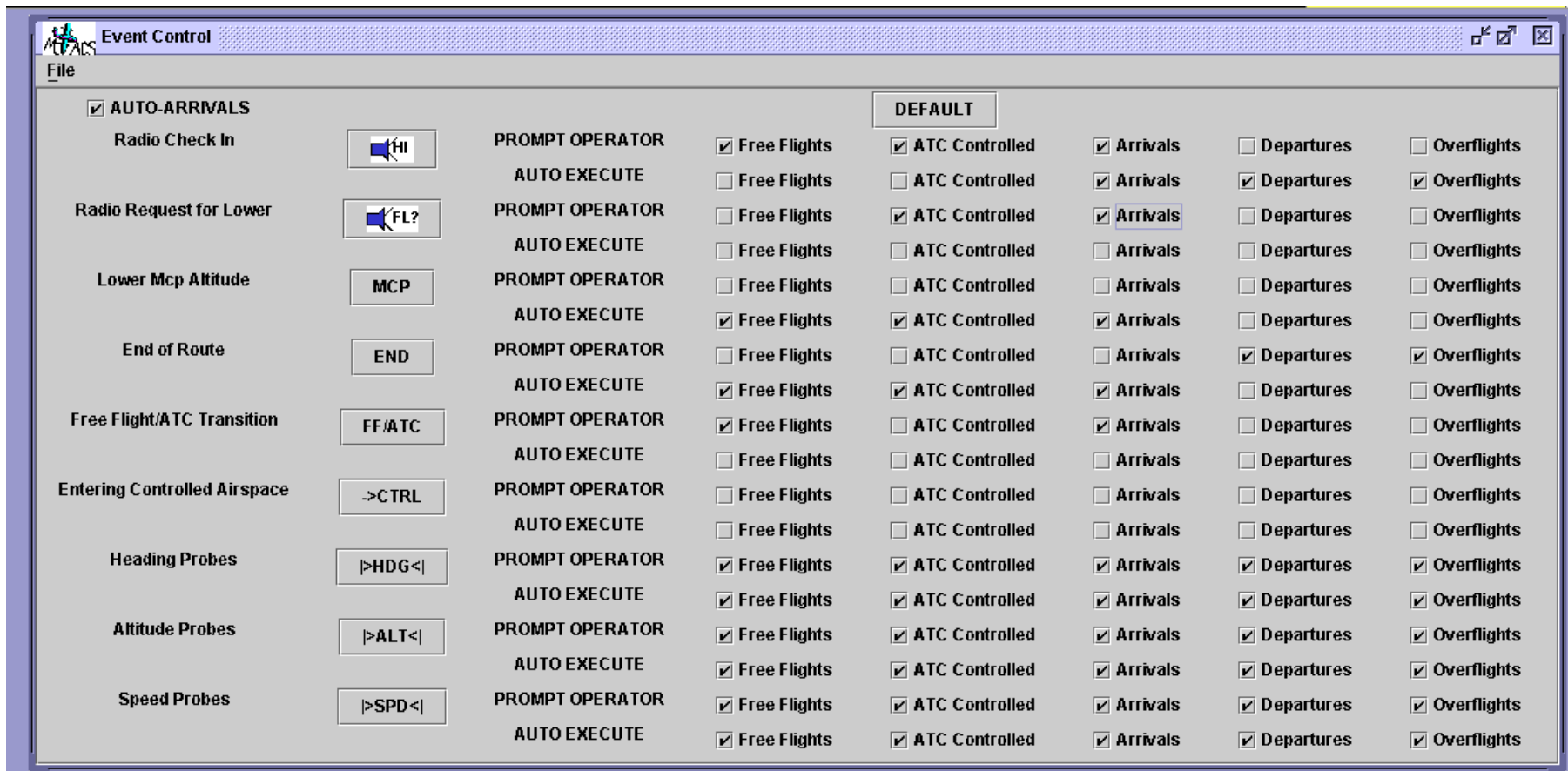
ADRS ON cedex CONNECTED AT 18:00:34

STATUS NOW RECEIVED REPORTED DELAY MINIMUM DRIFT OF-LEVEL

19:06:26	19:06:26	19:06:27	1.399	1.506	0.107	0	19:06:26
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ADRS-ON	TALKS VIA	TO	ON	5s Avg In Msgs Bytes	5s Avg Out Msgs Bytes ToGo	30s Avg In Msgs Bytes	30s Avg Out Msgs Bytes ToGo	RECEIVED
cedex.arc.nasa.gov	MPI	JAVA PILOT STATION	oakey.arc.nasa.gov:2	0 0	16 15254 0	0 0	47 15055 0	19:06:26
cedex.arc.nasa.gov	MPI	ADRS (SERVER)	gates	45 14886 2	1227 0	46 15530 1	972 0	19:06:25
gates.arc.nasa.gov	MPI	ADRS (SERVER)	pueblo	44 14514 0	1976 0	44 14673 0	1976 0	19:06:25
gates.arc.nasa.gov	CENTER ISM	CTAS	heaftr.arc.nasa.gov	0 0	43 10335 0	0 0	40 12079 0	19:06:25
gates.arc.nasa.gov	CENTER ISM	CTAS	conny.arc.nasa.gov	0 0	43 10335 0	0 0	47 11061 0	19:06:25
pueblo.arc.nasa.gov	COMMON IF	PAS	pueblo	44 10706 0	54 0	44 10747 0	50 0	19:06:25
pueblo.arc.nasa.gov	ADS-B	PAS	pueblo	1 6312 0	0 0	1 6407 0	0 0	19:06:25
cedex.arc.nasa.gov	MPI	JAVA PILOT STATION	stins.arc.nasa.gov:3	1 175 16	15140 0	0 85 16	15611 0	19:06:25
pueblo.arc.nasa.gov	MPI	ADRS (CLIENT)	gates.arc.nasa.gov:3	3 1970 44	14514 0	2 1859 44	14711 0	19:06:25
gates.arc.nasa.gov	MPI	ADRS (CLIENT)	cedex.arc.nasa.gov:3	2 1227 16	14886 0	2 1220 16	15089 0	19:06:25

- MACS can be configured for automatically performing tasks or prompting operators

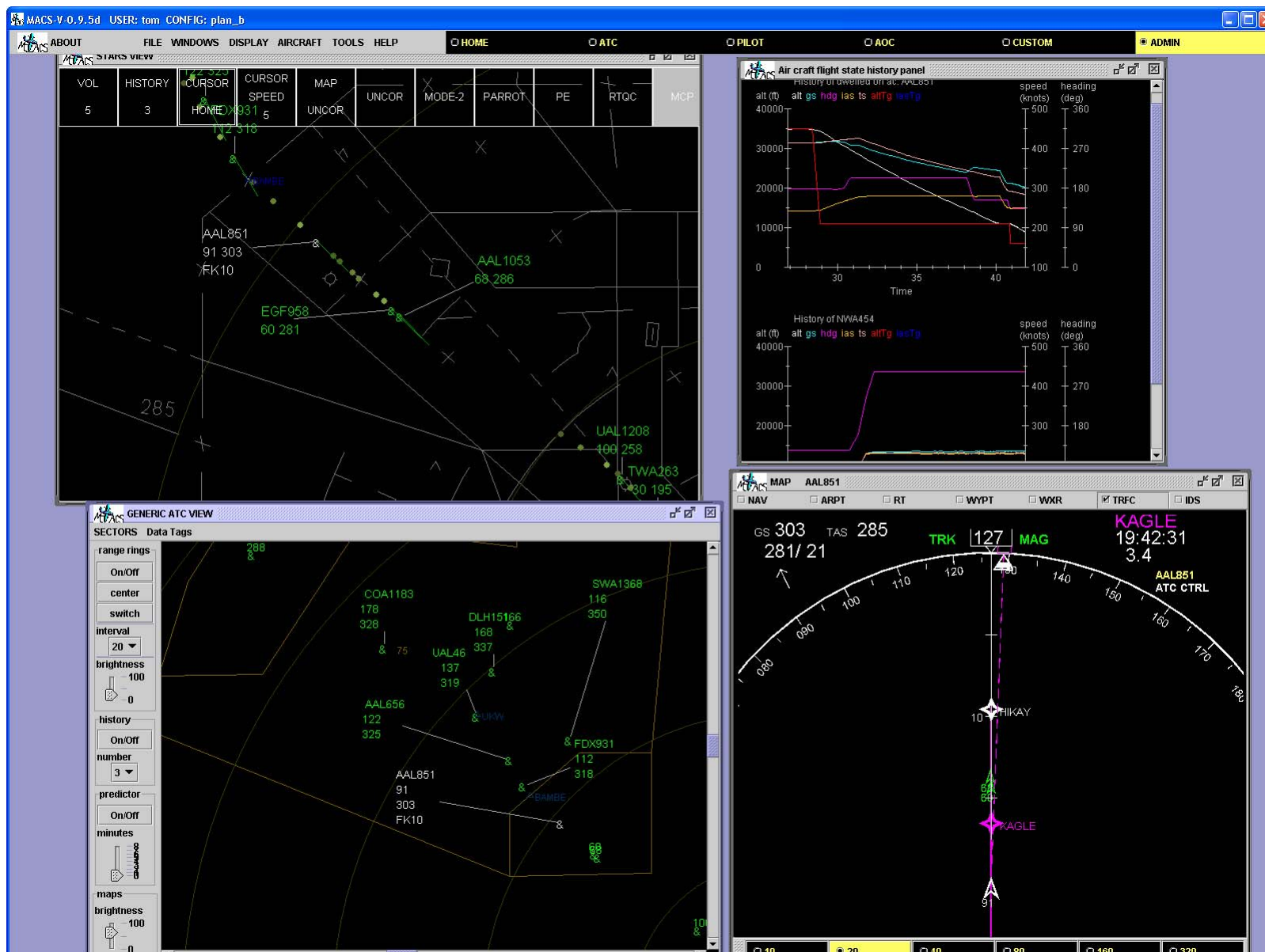


The screenshot shows the MACS Event Control window. The title bar is "Event Control" with standard window controls. Below the title bar is a menu bar with "File". The main area is divided into several sections:

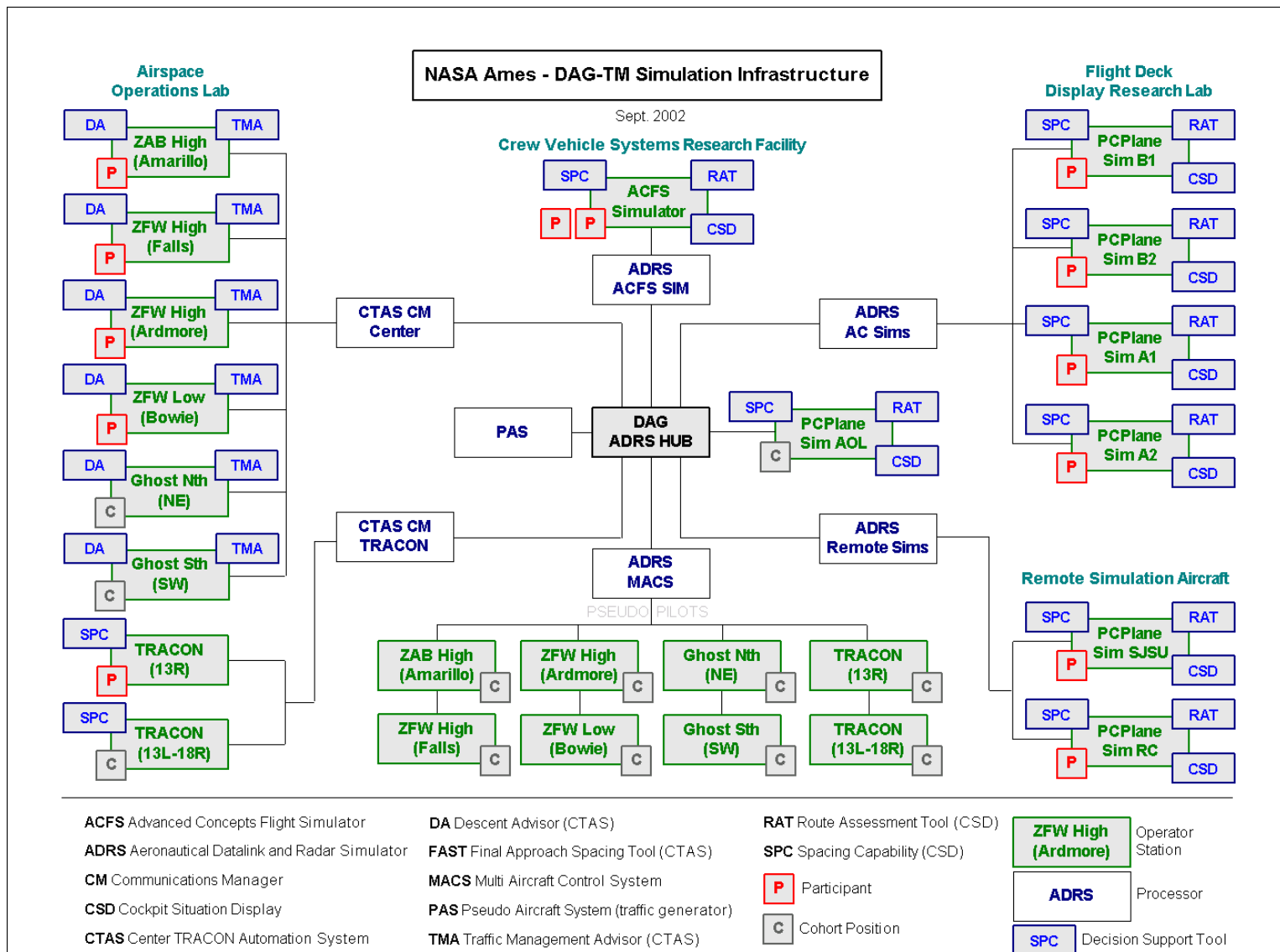
- AUTO-ARRIVALS**: A checkbox is checked. Below it are several event triggers with associated buttons:
 - Radio Check In: [HI]
 - Radio Request for Lower: [FL?]
 - Lower Mcp Altitude: [MCP]
 - End of Route: [END]
 - Free Flight/ATC Transition: [FF/ATC]
 - Entering Controlled Airspace: [->CTRL]
 - Heading Probes: [>HDG<]
 - Altitude Probes: [>ALT<]
 - Speed Probes: [>SPD<]
- PROMPT OPERATOR**: A column of labels for each event trigger.
- AUTO EXECUTE**: A column of checkboxes for each event trigger.
- DEFAULT**: A tab button.
- Configuration Columns**: A series of checkboxes for each event trigger, including:
 - Free Flights
 - ATC Controlled
 - Arrivals
 - Departures
 - Overflights

The "Arrivals" checkbox is highlighted in the "Arrivals" column for the "Radio Request for Lower" event.

MACS Windows



Current DAG Simulation Architecture

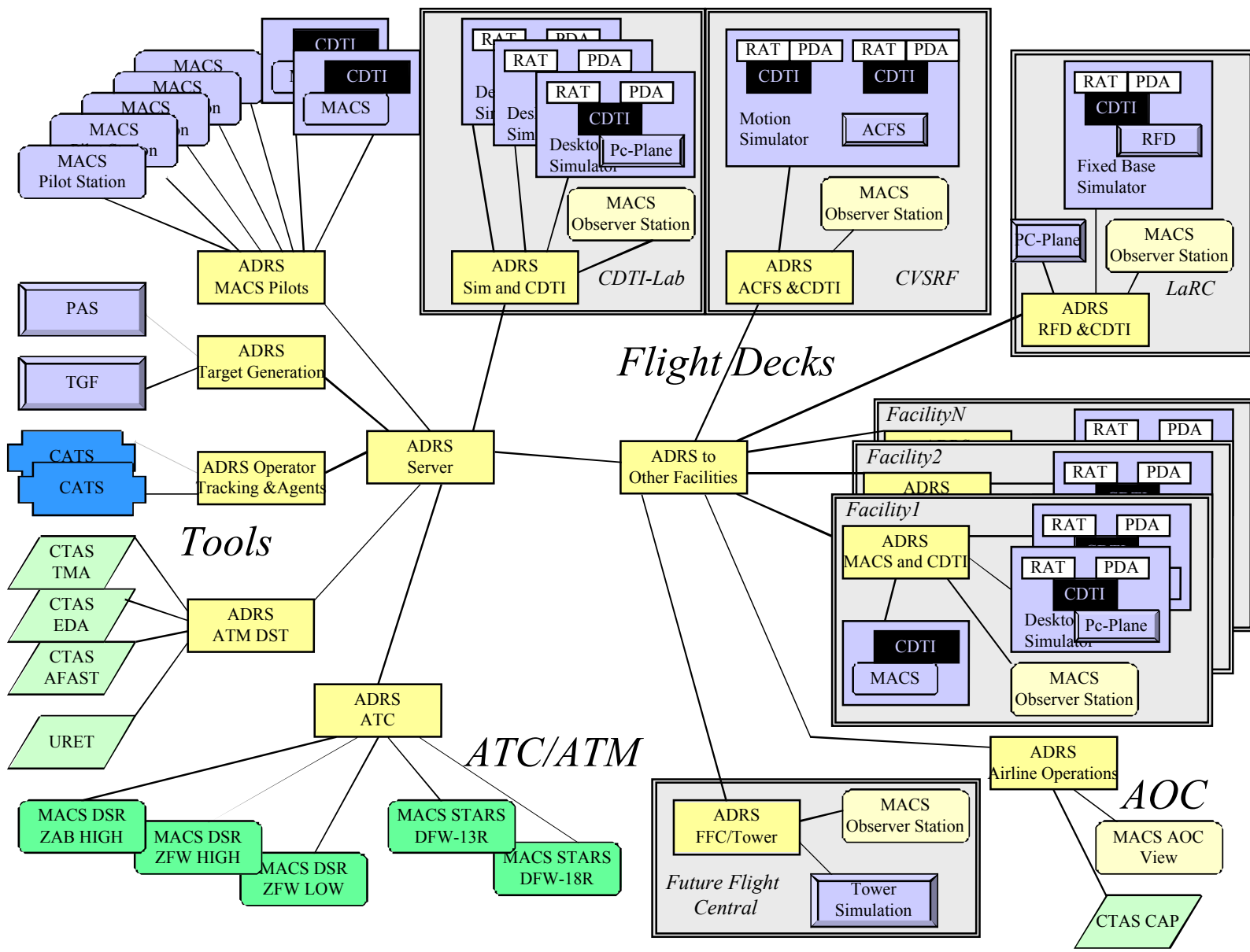
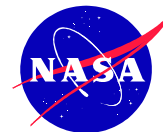


- **Aeronautical Datalink and RADAR Simulator*
- Distribution of communication load:
 - Unlimited number of servers and clients can be connected by adding identical ADRS processes to the simulation network that share their information
- Host emulation
- Radar simulation
- Datalink simulation
- Aircraft state and trajectory data harmonization and maintenance
- Process control and monitoring

MACS usage in current DAG Simulations (Ongoing)

- CTAS/FMS 2002 data collection. Evaluation of trajectory based vs. sector based concepts of managing arrival traffic with FPL controllers and air traffic managers.
 - AOL, MACS, PAS, CTAS
- Frequent workshops, demonstrations and evaluations of distributed concepts that investigate free-flight concepts with airborne and ground-based conflict resolution techniques, new separation responsibilities and airspace restructuring with controllers, pilots, dispatchers and researchers.
 - AOL, ACFS, PC-Plane, MACS, CDTI, PAS, CTAS

Upgrading and Expanding



Concluding remarks

- Realistic human-in-the-loop simulations of future distributed air traffic management will require participation of numerous pilots, controllers, airline dispatchers, researchers and the operational community alike
- The multi-fidelity simulation environment at NASA Ames has been successfully used for many demonstrations and evaluations
- The simulation will be upgraded and expanded to include more research facilities on and off-site as active participants, observers, or data analysts.
- Currently MACS is used for pilot stations and for automatically guiding aircraft. It will also replace the controller workstations.

http://human-factors.arc.nasa.gov/ihi/research_groups/air-ground-integration

http://human-factors.arc.nasa.gov/ihh/cdti/DAG_TM_WEB/dag2001.html

<http://www.arc.nasa.gov/aatt>